RAMAS® Ecorisk:

Software for rapid ecological risk analysis

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1. Introduction

A tool for rapid assessment of biological populations is needed because both resources and time are always limited in the real world. It is better to make an informed decision using limited data to its fullest than to make no decision at all. By quickly screening a set of species one can determine which species are threatened, and which are not. Resources and time can be more efficiently allocated to studying why certain species are threatened and conservation or management plans can be developed quickly to assist in the species recovery.

RAMAS Ecorisk uses stochastic simulations of population dynamics to calculate quasi-extinction risks that a population will be below a given density, and time to quasi-extinction, which is the probability that at a given time the density will have fallen below a specified threshold density. The four discrete stochastic models used to simulate population dynamics are Malthusian growth, Malthusian with a ceiling, Malthusian with a time-delayed ceiling, and Ricker's model of density-dependent growth. Parameters for the model can be entered individually as positive real numbers or as intervals covering a range of values. If no demographic information for a species exists, the parameters can be estimated from the species' body mass, class, and dietary preference.

When examining the potential effects of an impact on a population, one needs to distinguish between the background risk due to environmental noise and the risk associated with the impact. RAMAS Ecorisk can calculate the change in risk or Δ risk resulting from the impact. Impacts can be specified as either a percent change in density per time-step, or as single or multiple changes in model parameters.

2. Installing the software

RAMAS Ecorisk Importer requires Python, a dynamic scripting language, to run. Python is free software that can be commercially redistributed. The software can be downloaded from the Web through the following url: http://www.python.org/. Python 2.2, the latest version, is included in the delivery of this task. Once Python has been installed, RAMAS Ecorisk Importer can be run from the Ecorisk folder in the programs menu.

To install RAMAS Ecorisk, insert the CDROM titled RAMAS Ecorisk. Go to “My Computer,” which is on the desktop, and double-click on the drive icon titled “RAMAS_Ecorisk.” Then click on “Setup” to install the software. From now on, the software wizard will guide you through the rest of the installation process.

3. Entering ecological parameters

3.1 How parameters are specified

Parameters can be specified in several forms in an entry-box for the parameter. If there is an error entering a parameter, then an error message is displayed in the entry-box.

Scalars

Numbers can be specified as 50.634 or in scientific notation as 5.634e1.

Outward rounded scalars

Since measurements are made with finite precision and calculations are carried through with finite precision outward rounding bounds errors from these sources. A scalar entered as [5.6] is transformed to [5.55,5.65], an interval.

Intervals

Due to measurement error and/or lack of knowledge, parameters can be specified as intervals. This is done by entering in square brackets the lower range separated by a comma from the upper range; for example, [0.026,0.53] or in scientific notation [2.6e-2,5.3e-1].

3.2 Essential model parameters

These are the parameters that need to be entered to simulate the most basic aspects of a population.

***T*:** the time horizon or the number of years the simulation is to be run. Since the simulation of population dynamics is discrete the time horizon has to be a positive integer. Time horizons of more than 20 years are beyond the predictable capabilities of most simulations and should be viewed with care. If no density-dependence has been set and a large time horizon has been entered (for example, more than 20 years), the population can grow to biologically unrealistic densities.

θ: the threshold density or critical density that the population should not fall below. If the value is set above *N*, the probability of falling below θ will be 1.0 at a later point in time; therefore, θ should be set below the starting density. The threshold density must be a scalar.

***N*:** the starting or initial density for a simulation. The units of *N* is number of individuals per square kilometer. The density must be greater than 0. The value for *N* entered can be a scalar or an interval.

***r*:** the average intrinsic growth rate expressed on a per-year basis. If *r* is set to zero, the average population growth is zero; if it is positive, then the population will grow on average; and if it is negative, the population will decrease in size on average.

σ: allows the standard deviation around the intrinsic rate of growth. The value of σ can be equal to zero. In that case, if the simulation is deterministic or greater than zero, then the simulation is stochastic. The value σ can be entered as a scalar or as an interval.

4. Density-dependence

Density-dependence is invoked by clicking on the carrying capacity button located in the lower left-hand corner of the main window. Clicking the button creates a drop-down list for selecting the type of density and an entry-box for *K*. Density dependence can be turned off by selecting Malthusian from the drop-down list.

Density-dependence drop-down list: select the type of density-dependence that will be invoked in the simulation of the population's dynamics.

- Unknown: Currently not implemented.
- Malthusian: Exponential growth model with no form of density-dependence. This is the default for all new simulations.
- Ceiling: The population density cannot exceed the carrying capacity in this model.
- Time-delayed ceiling: The population density is allowed to exceed *K* but at the next time-step, the density falls to *K* in this model.
- Sharing: or Ricker is a model for species that roughly share resources equally.
- Territorial: or Beverton-Holt is a model for species that partition resources unequally.

***K*:** The carrying capacity or the mean ecological density is expressed as a density in the units number of individuals per square kilometer. The value of *K* can be a scalar or an interval and must be greater than zero.

5. Estimating parameters from body mass

The estimate parameter modal window allows estimates of r, σ, and *K* to be made from the body mass of an organism. It is invoked from the estimate icon in the toolbox.

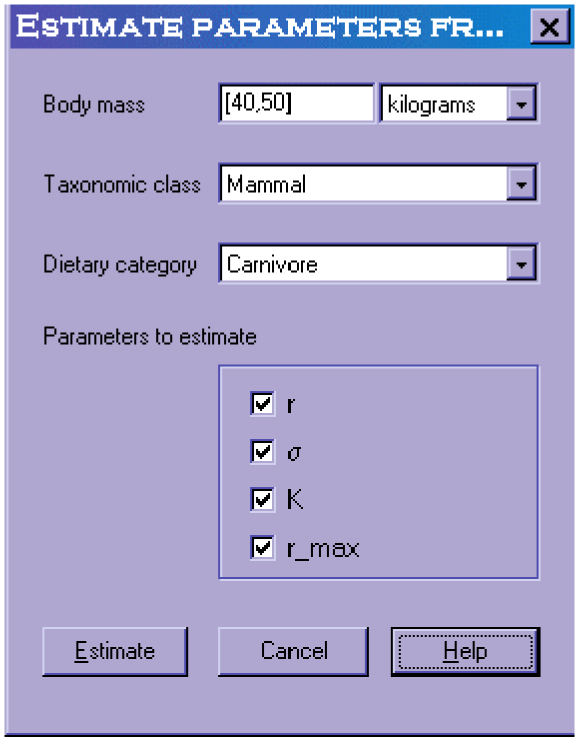

Figure 5.1: A screenshot of the estimate from body mass dialog.

Body mass of the organism: can be entered as a scalar or as an interval in several units: grams, kilograms, ounces, and pounds.

Taxonomic class drop-down list: for specifying the taxonomic class of the organism.

- Birds
- Mammals

Dietary drop-down list: allows the user to select a broad dietary grouping for the species.

- Herbivore: the diet of the species is primarily composed of leaves or grass that is browsed or grazed.
- Frugivore: the diet of the species is primarily composed of fruit and seeds.
- Insectivore: the diet of the species consists primarily of invertebrates like insects or crustaceans.
- Carnivore: the diet of the species consists mainly of vertebrate tissue.
- Unknown: dietary grouping of the species is unknown.

These broad dietary groupings are used to get a better estimate of *K*, the carrying capacity.

Estimate parameters check-boxes: Check all or a subset of r, σ, or *K* check-boxes to estimate the parameter from body mass.

Estimate button: Will estimate the checked parameters from the body mass using the entered information on the form. The estimated values will overwrite previous values in the main form.

6. Specifying an impact

The simplest kind of impacts can be entered as a percent change in abundance or carrying capacity. By clicking the toggle trends button, the following entry-boxes will appear:

ΔN **%** The percent decrease in abundance at each time-step in a simulation could represent the impact of a chemical to a population. The default value is set to zero for no impact. Values must be zero, negative, or a positive number less than 100 and can be entered as a scalar or as an interval.

ΔK **%** The percent decrease in carrying capacity at each time-step. The default value is set to zero for no impact. Values must be zero, negative, or positive less than 100 and can be entered as a scalar or an interval.

To hide the trends entry-boxes, click the toggle trends button. If trends are hidden when the simulation is run, the results will show only the results of the non-impacted population.

More advanced impacts can be specified as changes in ecological parameters. Clicking the impact button creates additional entry-boxes for specifying the impact as changes in the basic ecological parameters. The entry-boxes appear to the right of the basic ecological parameters.

7. Running a simulation

To run a simulation, press the view results icon  in the toolbox. This is probably the easiest and most exciting part of evaluating the viability of a population.

8. Results

Results can be paged through using the next or previous button or using the PgDn or PgUp keystrokes. The following results are currently supported:

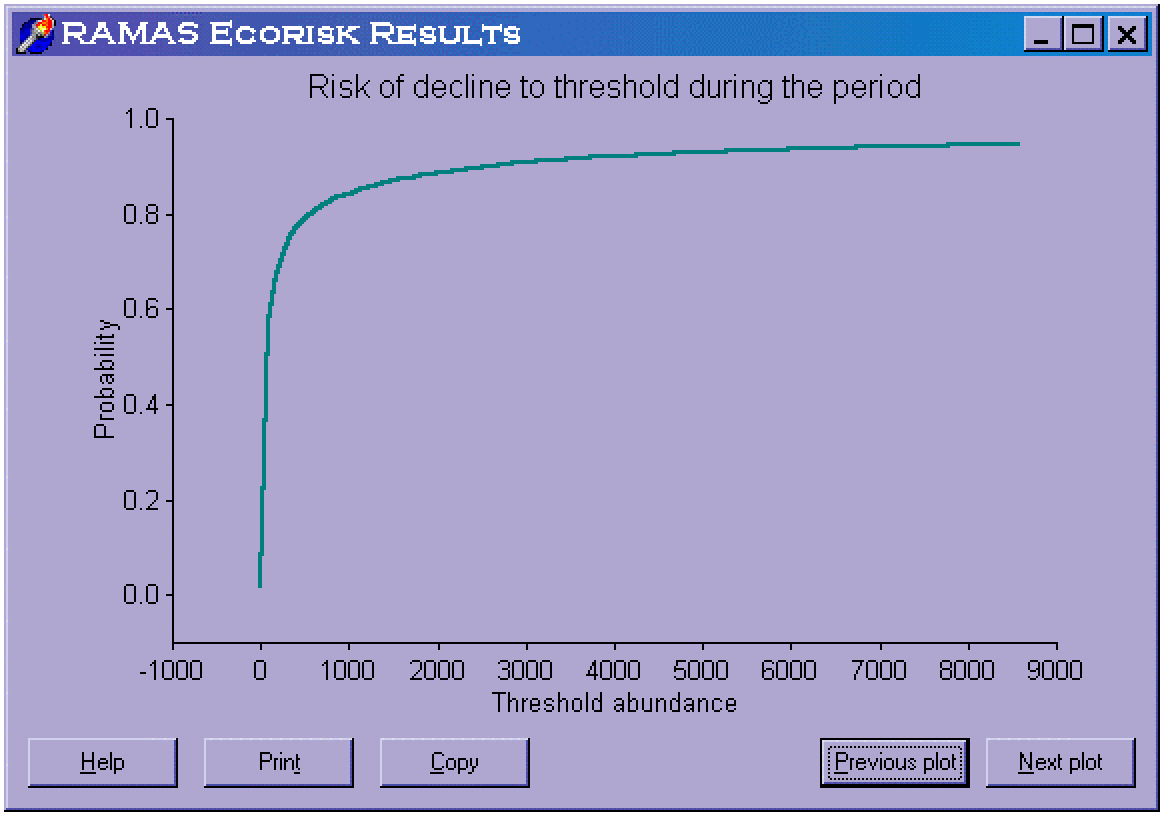

Figure 8.1: An example screenshot of the quasi-extinction decline curve.

Decline to threshold (during)
Plots the probability that during a simulation, the trajectory for a range of densities has fallen below a specific density.

Decline to threshold (at the end)
Plots the probability that at the end of a simulation, the density for a range of densities has fallen below a specific density.

Time to decline
Plots the probability that the density for a range of time-steps has dropped below a specified θ, threshold level, at that time-step.

Trajectory summary
Plots the maximum density reached, the minimum density reached, and bounds on the arithmetic mean for each time-step.

If a parameter has been specified as an interval, then lower and upper bounds for a risk curve will be generated. The curves bound all possible risk curves given the uncertainty in a single or multiple parameters. If an impact has been specified, then the risk curve for the impact will appear solid compared to dotted for the background risk.

9. Configure results

Allows selection of which results will be available after running the model.

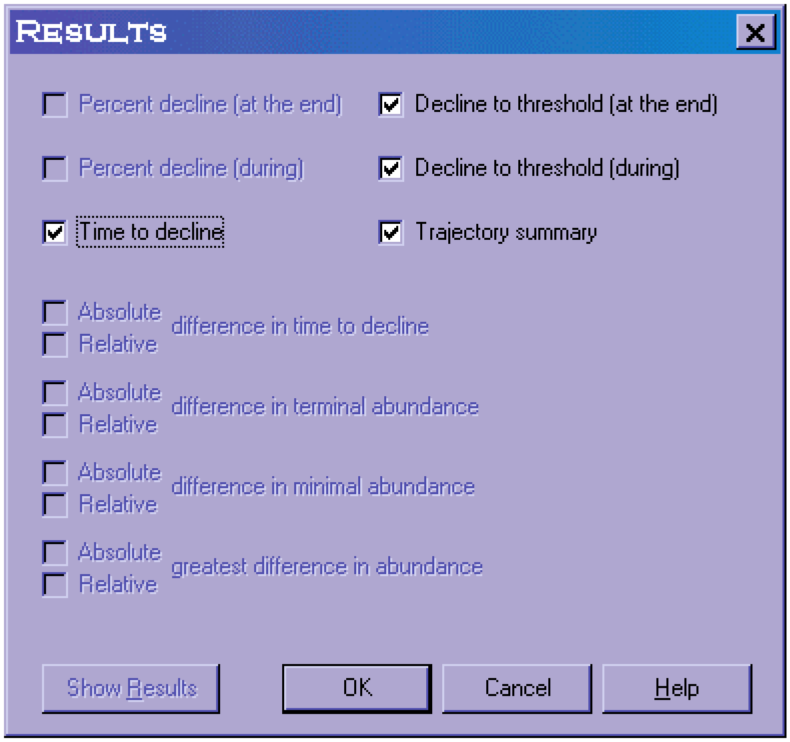

Figure 5.1: A screenshot of the configure results dialog.

10. Options

General configurations that effect how a model is run and how input data are treated can be set in the options dialog.

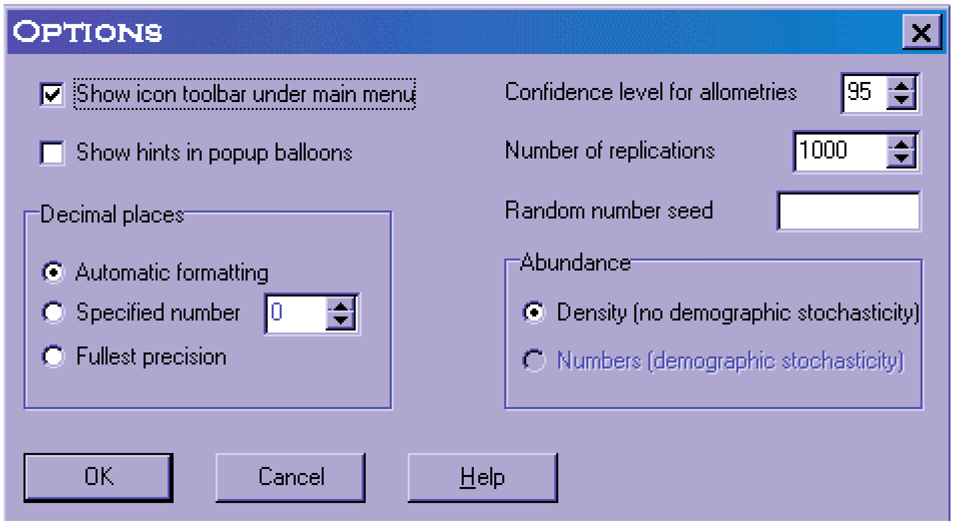

Figure 10.1: A screenshot of the options dialog.

Show icon toolbar under main menu: Enable or disable the toolbar with icons under the drop-down menus.

Show hints in popup balloons: Enable or disable popup balloons, which provide helpful hints over entry dialogs.

Decimal places: When entering a number in an entry box for a model parameter, the options below specify how numbers are displayed and rounded.

- Automatic formatting: When specifying intervals, will automatically truncate and round outward the endpoints of the interval based on how wide the interval is.
- Specified number: For both intervals and scalars, set the fixed precision of intervals.
- Fullest precision: Displays the fullest precision available when entering numbers.

Confidence level for allometries: When estimating parameters from allometry, confidence levels can be set. Confidence levels are set as a percentage. A confidence level of 0 gives a point estimate, and as the percentage increases, the bounds increase around the point estimate.

Number of replications: Allows the user to set the number of replicates the model runs. Small number of replicates will run faster but the results will be less reliable.

Random number seed: Lets the user set the random seed for the pseudo-random number generator. The seed must be an integer.

Abundance: Currently, demographic stochasticity is not supported in Ecorisk.

11. Using RAMAS Ecorisk Importer

The software imports a time series as a text file and outputs it as a "*.rsk" file, which RAMAS Ecorisk can read. Text files can be tab or space delimited. Tab-delimited files can be generated from Microsoft Excel spreadsheets. The text file can have at most two columns.

For a time series without gaps in the sampling, the file can be a single column of positive numbers. The following shows how a time series with gaps can be structured as a text file:

```
1       25
2       30
3       41
4       28
5       0
8       12
9
10
11      23
23      25
```

The first column contains the year and the second column the associated abundance. The year must be given as an integer and the abundance can either be given as an integer or as a floating point number (e.g. 2.4 or 3.0e2).

Once a text file is correctly structured it can be imported into the software by clicking the import button. This will bring up an open file dialog, which allow you to select the appropriate file (Figure 11.1).

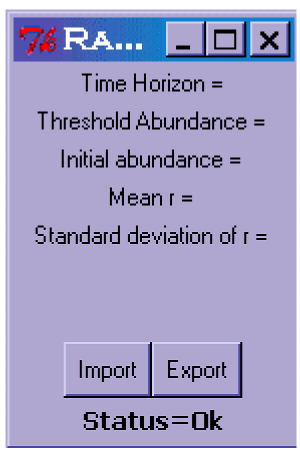

Figure 11.1: Screenshot of RAMAS Ecorisk Importer at startup.

When the file is selected and the open button is pressed, the series will be read into memory and estimates of the parameters will be made. If there is an error in the series, then an appropriate status message will be displayed on the bottom of the window.

RAMAS Ecorisk Importer will display estimates of the parameters, the number of time points and the number of continuous fragments that compose the series (Figure 11.2). The next step is to export the series in a format that RAMAS Ecorisk can read from. This is done by clicking the export button and will bring up a save file dialog, which allows the creation of an "*.rsk" file. Currently, RAMAS Ecorisk will export the starting abundance of the series, the time span of the series, the mean *r*, and the standard deviation of the mean *r*.

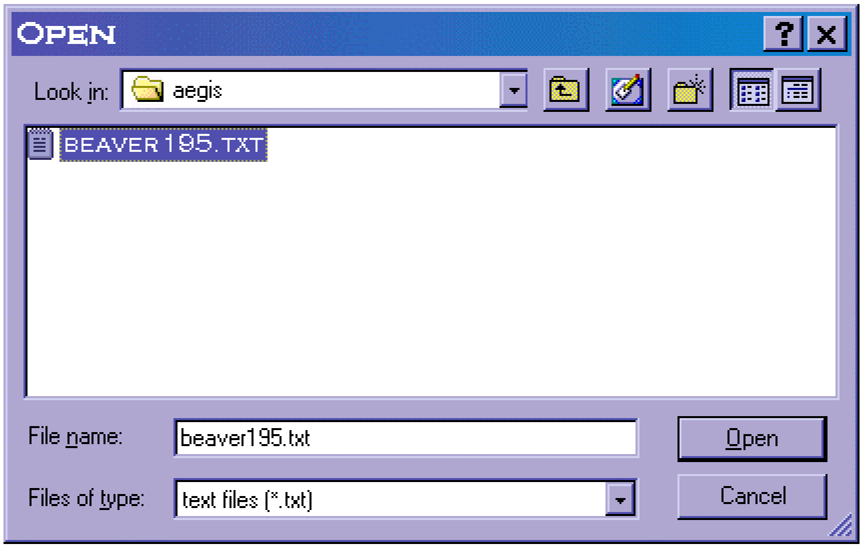

Figure 11.2: The open file dialog, which is used to import a time series.

Figure 11.3: A screenshot of RAMAS Ecorisk Importer having successfully imported a time series.

12. Additional information

Rather than boring the reader with a complete account of the science behind RAMAS Ecorisk, additional sources of information are provided here.

PVA (Population Viability Analysis): RAMAS Ecorisk is a tool for doing probabilistic risk assessment at the population level. An excellent introductory textbook to probabilistic risk assessment is *Applied Population Ecology* by Akçakaya et al. (1999). Two model endpoints, the risk of quasi-extinction decline and the time to quasi-extinction decline, were first introduced by Ginzburg et al. (1982) for continuous stochastic models. In the case of RAMAS Ecorisk discrete stochastic models were used to simulate population dynamics. A recent validation of population viability analysis was completed by Brook *et al.* (2000).

Density-dependent models: There is a rich literature on the effects of density dependence on population dynamics. The ceiling model and delayed ceiling models are implemented in most RAMAS software. Ricker (1975) and Beverton and Holt (1959) models of density dependence are widely used in assessing the viability of fisheries. The effects of density dependence on the calculation of quasi-extinction decline is explored by Ginzburg et al. (1990).

Ecological allometries: There is a rich literature on scaling or allometric relationships in biology. The best introduction to the literature is from Calder (1984). Allometric relationships relate the value of an ecological parameter to the body mass of a species as a scaling power. The best known allometric relationship is the ¾ scaling of basal metabolic rate to body mass (Kleiber 1932). Ther two ecological scaling relationships that RAMAS Ecorisk uses are r_m and K. The maximum intrinsic rate of increase scales approximately between 1/3 and 3/4 scaling rate (Blueweiss et al.,1978; Fenchel, 1974; Schmitz and Lavigne, 1984; Thompson, 1987). Carrying capacity or K scales as a – ¾ power to body (Damuth, 1981, 1987).

Estimating parameters from time series: Besides providing a history of a population, a time series can be used to estimate parameters for ecological parameters. A good reference to analytical population dynamics is Royama (1992). Ecological time series often have gaps in year-to-year sampling. To handle these gaps, an omission model is used by RAMAS Ecorisk Importer. For information about omission models, see Lewellen and Vessey (1999), and for an alternative approach to gaps, see Palma and Pino (1999).

14. Example

Wolf (*Canis lupus*)

Quasi-extinction risk decline was calculated for the wolf (*Canis lupus*) population on Isle Royale, Michigan, U.S.A. Estimates of the risk of decline were compared between those calculated from a stochastic matrix model in RAMAS Metapop (Akçakaya and Root, 2002). The matrix model of the wolf by Brook et al. (2000) has four stages with 40 individuals spread among these stages.[1] The adult body mass of a wolf in the population from Isle Royale ranged from 35 to 50 kilograms (Peterson and Page, 1988). Upper and lower estimates of the 95percent confidence limits for σ_r are 0.438 and 0.645, respectively.

In addition, estimates of r and σ were made from the database of time series included with RAMAS Ecorisk. The average r=-0.014 and σ_r=0.69 were calculated from nine time series obtained from the GPDD. The values for r ranged from [-0.69,0.053]and σ_r from [0.15,1.21].

For the wolf population of Isle Royale the quasi-extinction decline risk was calculated for a twenty year time horizon. Figure 14.1 compares the quasi-extinction decline risk for the scalar model with allometric estimated parameters and the age structured with parameters estimated directly from demographic data. These results show that both scalar models are more conservative when compared to an age-structured model, in terms of the risk of quasi-extinction decline.

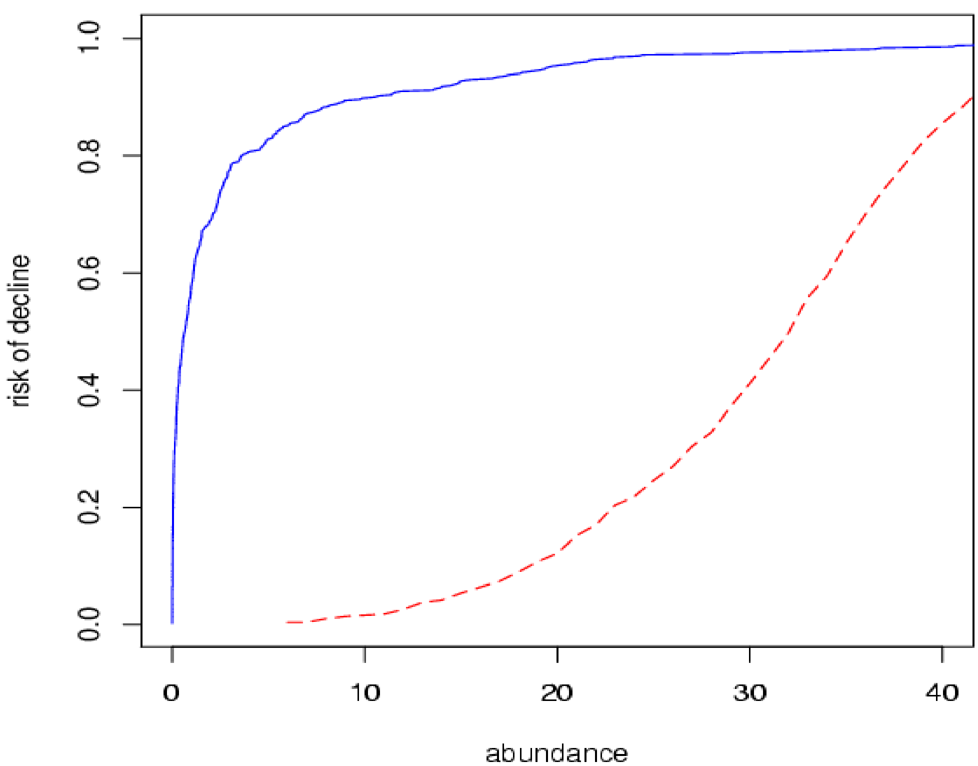

Figure 14.1: Quasi-extinction declines risk curves for *Canis lupus* generated from a scalar model with the parameters estimated from allometry (unbroken line), time series data (dotted line), and an age-structured

[1] This model is available as an online supplement to Brook et al. (2000) at http://www.nature.com.

model estimated from historic demographic data (dashed line). The following parameters were used to parameterize the scalar model with allometric coefficients: r=-0.208, and σ_r=0.645, and for the scalar model with parameters estimated from time series are: r=-0.014 and σ_r=0.69.

A chemical impact occurred on the Isle Royale. The impact, a chemical with a very short half-life, caused an initial 50 percent mortality to the wolf population. The chemical acting across the different age classes[2] reduced the total population size to 20 individuals. Using the same values for r and σ_r quasi-extinction decline curves were generated for the simple and the complex model (Figure 14.2).

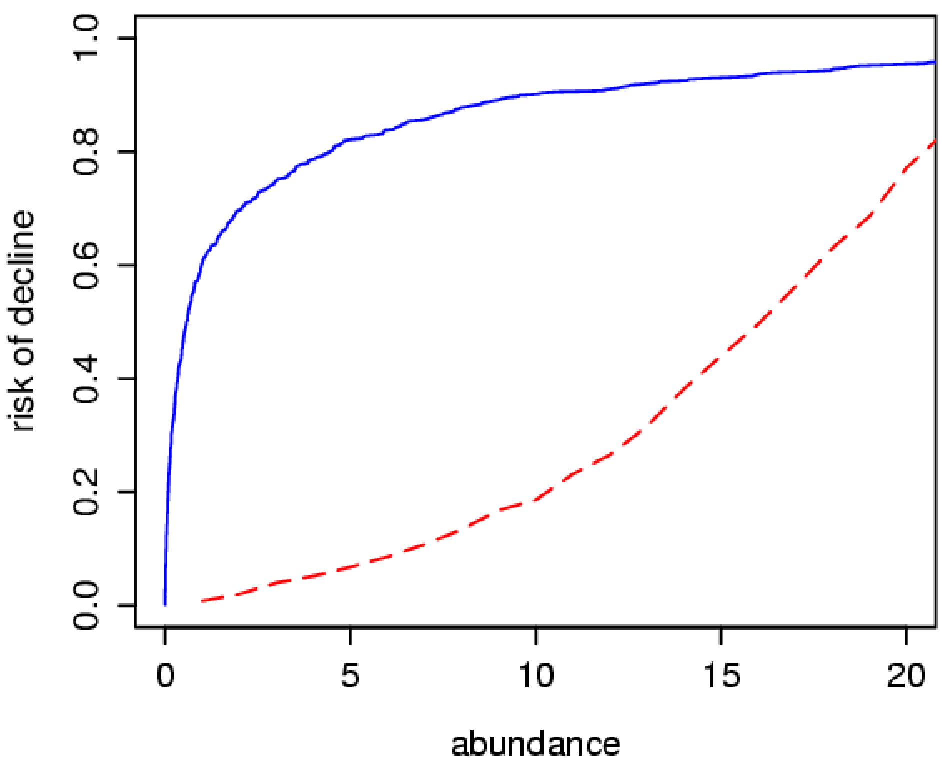

Figure 14.2: Hypothetical example of a chemical pulse impact that imposed an initial 50% reducing the total population size to 20 wolves. The quasi-extinction decline risk curves for the example was generated from a scalar model with the parameters estimated from allometry (unbroken line) and an age structured model estimated from historic demographic data (dashed line). The following parameters were used to parameterize the scalar model: r=-0.208, σ_r=0.645, and T=20 years.

Red-tailed hawk (*Buteo jamaicensis*)

The red-tailed hawk model is a stage-structured model[3] from Ferson & Akçakaya (1990) based on data collected by Copley. In the model, there are 575 birds distributed among three stages. An adult hawk was

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[2] The 50 percent could not act equally across the different age classess because one age class had an odd number of individuals.
[3] This file is distributed as part of RAMAS Metapop.

found to have a mean mass of 1.2 kilograms (Dunning, 1993). The 95 percent confidence limits for σ_r when estimated from allometry are 0.58 and 0.84. Making the adjustment to *r* for the non-linearity of the transformation, we have r=-0.35. As with the example of the gray wolf, time series data were used to estimate parameters from the model (r = 0.0026 and σ_r=0.927). The three quasi-extinction decline risk curves are plotted in Figure 14.3.

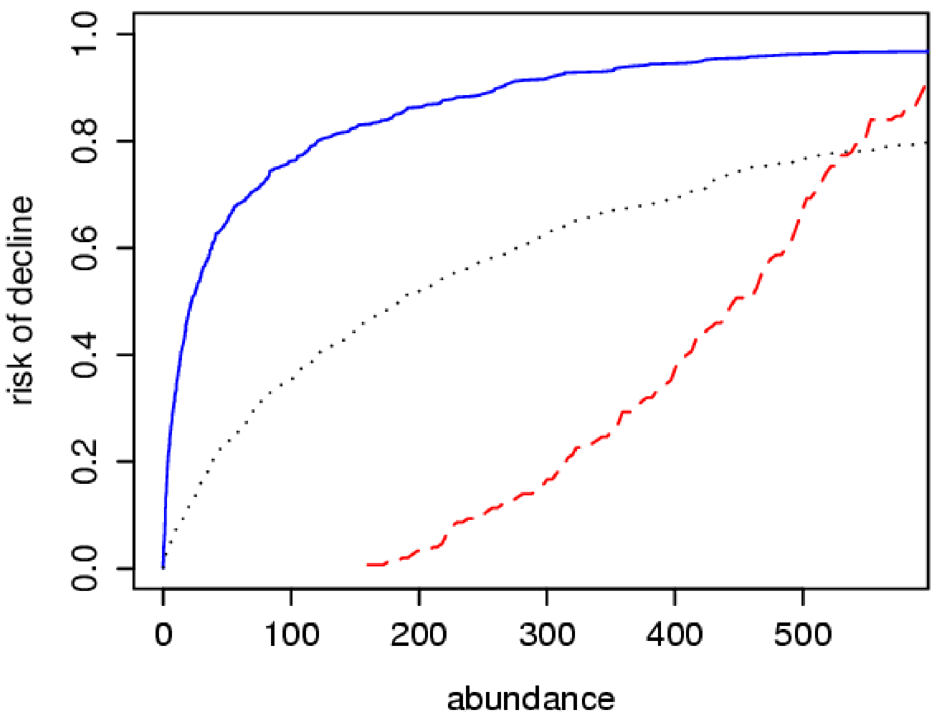

Figure 14.3: Quasi-extinction decline risk curves for *Buteo jamaicensis* generated from a scalar model (T=20 years),with the parameters estimated from allometry (unbroken line), from a scalar model with the parameters estimated from a time-series (dotted line), and an age structured model estimated from historic demographic data (dashed line). The following parameters were estimated from allometry and a time series: r=-0.35 and σ_r=0.833, and r=0.0026 and σ_r=0.927, respectively.

A chemical with a longer half-life in the environment acts to reduce the survivorship of juveniles by 50 percent; a well-known example of such a group of chemicals which affect predatory birds are PCBs. For the matrix model, this can be easily modeled by reducing the survivorship to age 1 from 0.48 to 0.24. In the case of allometry-estimated parameters, it is not clear how to reduce the survivorship of individuals in the population because such a chemical acts on individual survivorships, not on a population-level attribute. The simple stochastic scalar model's parameters are estimated from historic trend data and not biological data of individual survivorships. This makes comparison of the risk of decline between the two models impossible without some additional information.

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